IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re continuation application of U.S. Patent Application Serial No. 09/441,201, filed November 16, 1999, Art Unit 1725, Examiner Samuel M. Heinrich

Applicant : Donald V. Smart
Filed : January 7, 2001
Title : LASER PROCESSING

Commissioner for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT

Prior to examination, please amend the application as follows:

In the specification:

On page 1 between lines 3 and 4 insert the following:

Cross-Reference to Related Applications

This is a continuation of U.S. patent application serial no. 09/441,201, filed November 16, 1999, which is a continuation of U.S. patent application serial no. 08/774,107, filed December 24, 1996, now U.S. Patent No. 5,998,759.

Replace the paragraph beginning at page 19, line 18 with the following rewritten paragraph:

-- As has been mentioned above, in the embodiment of Fig. 5, a conventional laser 10 with a very short pulse width, designed to maintain this pulse width over a substantial range of laser repetition rates, is introduced into a system that includes a wavelength shifter 12. The conventional laser 10 at 1.064 microns or 1.047 microns typically has a very high gain and can be easily designed to develop the requisite short pulse. A laser configured to intrinsically have the longer wavelength, such as the 1.32-micron wavelength of YAG or YLF, would have intrinsically low gain and hence will have a pulse width much longer than desired. The $Nd:VO_4$ (vanadate) laser 10 has very high gain and constant pulse width at high repetition rates operating at 1.064 microns. The wavelength shifter 12 (such as a stimulated Raman scattering laser) can

shift the wavelength to beyond the absorption edge of silicon without increasing the laser pulse width. --

Replace the paragraph beginning at page 20, line 27 with the following rewritten paragraph:

-- Let us examine the laser aspects that make up the single pass gain. It is dependent upon the power density of the light source used to "pump" the laser, the efficiency of conversion of this power to useful laser output, and the material characteristics of the lasing medium. The relationship is given as follows:

$$\text{Gain} = EP/[I_{sat}(A_{pump}+A_{mode})]$$

where E is the efficiency of conversion of pump light to laser output, P is the pump power (i.e., the effective power delivered by the laser diode), I_{sat} is a material parameter dependent on the laser material and its doping, A_{pump} is the cross-sectional area covered by the pump beam in the laser rod, and A_{mode} is the cross-sectional area of the laser mode within the laser rod. --

Replace the paragraph beginning at page 24, line 25 with the following rewritten paragraph:

-- Fig. 9 shows the pulse width for the three different materials as a function of repetition rate. Not only does the YVO_4 (vanadate) have the shortest pulse width, but it maintains this pulse width over a very wide range. --

<u>In the claims</u>:

Cancel claims 1-56.

Add claims 57-87:

-- 57. A laser-based method of vaporizing and removing a target link structure on a semiconductor wafer comprising the steps of:

providing a target link structure supported on a silicon substrate, the substrate being part of a semiconductor memory device;

producing a laser beam having a pulse width less than about 8 nanoseconds, an operating repetition rate of 10 kilohertz or higher, and a wavelength less than 1.2microns;

generating computer-controlled timing signals synchronized with position of the laser beam relative to the target link structure;

controllably switching an optical switch based on the timing signals so as to transmit an output pulse of the laser beam to the target link structure on demand, the output pulse rate being controlled by controlling the optical switch;

focusing the output pulse onto the target link structure into a spot diameter;

whereby the spot size and depth of focus is improved relative to a longer wavelength greater than 1.2microns, and the output pulse width limits damage to the substrate.

58. The method of claim 57 further comprising the step of mounting the device on a movable stage.

59. The method of claim 58 wherein the movable stage is a step and repeat stage.

60. The method of claim 57 wherein the target link structure comprises metal.

61. The method of claim 57 wherein a maximum processing rate exceeding 10,000 target link structures per second is achievable with a repetition rate of greater than 10 KHz.

62. The method of claim 57 wherein the step of generating computer-controlled timing signals includes correlating the timing signals with the position of the laser beam and the target link structure during relative motion between the laser beam and the target link structure;

63. The method of claim 62 further comprising positioning the beam with a galvanometer, and synchronizing the timing signals with the galvanometer positions.

64. The method of claim 57 wherein the optical switch is disposed in an optical path and is positioned beyond the laser cavity and external to the laser cavity;

65. The method of claim 57 wherein the output pulse width is less than 5 nanoseconds.

66. The method of claim 57 wherein the correlating step further comprises providing accuracy of better than .3 microns between the laser beam and the target link structure.

67. The method of claim 57 wherein the step of controllably switching the optical switch further comprises controlling an acousto-optic modulator to prevent an output beam from

reaching a target link structure except when desired, and controlling an acousto-optic optic modulator to set the output power to a desired level.

68. A laser-based method of vaporizing and removing a target link structure on a semiconductor wafer comprising the steps of:

providing a target link structure supported on a silicon substrate, the substrate being part of a semiconductor memory device

producing a laser beam having a pulse width less than about 8 nanoseconds, an operating repetition rate of 5 kHz or higher, at a first laser wavelength;

generating computer-controlled timing signals synchronized with position of the laser beam relative to the target link structure;

shifting the first laser wavelength to a second laser wavelength, the second wavelength being less than 1.2microns;

controllably switching an optical switch based on the timing signals so as to transmit an output pulse of the laser beam to the target link structure on demand, the output pulse rate and pulse spacing being controlled by the controlling the optical switch;

focusing the laser output pulse onto the target link structure into a spot diameter, the output pulse having a wavelength less than 1.2microns and a pulse width less than about 8 nanoseconds;

whereby the spot size and depth of focus is improved relative to a longer wavelength greater than 1.2microns, and the output pulse width limits damage to the substrate.

69. The method of claim 68 further comprising the step of mounting the device on a movable stage.

70. The method of claim 69 wherein the movable stage is a step and repeat stage.

71. The method of claim 68 wherein the target link structure comprises metal.

72. The method of claim 68 wherein a maximum processing rate exceeding 10,000 target link structures per second is achievable with a repetition rate of greater than 10 KHz

73. The method of claim 68 wherein the step of generating computer-controlled timing signals includes correlating the timing signals with the position of the laser beam and the target link structure during relative motion between the laser beam and the target link structure;

74. The method of claim 68 wherein the optical switch is disposed in an optical path between a wafer and a laser, and is positioned beyond the laser cavity and external to the laser cavity.

75. The method of claim 68 wherein one of the first and second wavelengths is beyond the absorption edge of the silicon substrate and one of the first and second wavelengths is not beyond the absorption edge of the substrate.

76. The method of claim 75 wherein the wavelength less than the absorption edge is less than about 1.12 microns.

77. The method of claim 76 wherein the wavelength less than the absorption edge is about 1.047 microns.

78. The method of claim 76 wherein the wavelength less than the absorption edge is about 1.064 microns.

79. The method of claim 71 wherein both the first and second wavelengths are less than 1.2 microns.

80. The method of claim 71 further comprising positioning the beam with a galvanometer, and synchronizing the timing signals with the galvanometer positions;.

81. The method of claim 71 wherein the output pulse width is less than 5 nanoseconds.

82. The method of claim 71 wherein the correlating step further comprises providing accuracy of better than .3 microns between the laser beam and the target link structure.

83. The method of claim 71 wherein the step of controllably switching the optical switch further comprises controlling an acousto-optic modulator to prevent an output beam from reaching a target link structure except when desired, and controlling an acousto-optic optic modulator to set the output power to a desired level.

84. A method of vaporizing and removing a target link structure on a silicon substrate, comprising the steps of:

providing a controlled, switched laser system comprising a diode-pumped, solid-state laser assembly and a controllable switch for controlling the on/off state and power level of the laser assembly;

producing a laser beam output having an output pulse width less than about 8 nanoseconds at an operating repetition rate of about 5 kilohertz or higher, and a wavelength shorter than 1.2 microns; and

directing the laser beam output at the target link structure on the silicon substrate to vaporize and remove the target link structure;

whereby heating of the silicon substrate and hence damage to the silicon substrate is limited due to the output pulse width being less than about 8 nanoseconds.

85. A laser system for vaporizing and removing a target link structure on a semiconductor wafer, comprising:

a laser assembly configured to produce a laser beam having a pulse width less than about 8 nanoseconds, an operating repetition rate of 10 kilohertz or higher, and a wavelength of less than 1.2 microns;

a computer programmed to control timing signals synchronized with position of the laser beam relative to a target link structure supported on a silicon substrate, the substrate being part of a semiconductor memory device; and

an optical switch that is controllably switchable based on the timing signals so as to transmit an output pulse of the laser beam to the target link structure on demand, the output pulse rate being controllable by controlling the optical switch, the laser assembly being configured to focus the output pulse onto the target link structure into a spot diameter;

whereby the spot size and depth of focus is improved relative to a longer wavelength greater than 1.2microns, and the output pulse width limits damage to the substrate.

86. A laser system for vaporizing and removing a target link structure on a semiconductor wafer, comprising:

a laser assembly configured to produce a laser beam having a pulse width less than about 8 nanoseconds, an operating repetition rate of 10 kilohertz or higher, and a first wavelength, and configured to shift the first laser wavelength to a second laser wavelength, the second wavelength being less than 1.2microns;

a computer programmed to control timing signals synchronized with position of the laser beam relative to a target link structure supported on a silicon substrate, the substrate being part of a semiconductor memory device; and

an optical switch that is controllably switchable based on the timing signals so as to transmit an output pulse of the laser beam to the target link structure on demand, the output pulse rate being controllable by controlling the optical switch, the laser assembly being configured to focus the output pulse onto the target link structure into a spot diameter;

whereby the spot size and depth of focus is improved relative to a longer wavelength greater than 1.2microns, and the output pulse width limits damage to the substrate.

87. A controlled, switched laser system for vaporizing and removing a target link structure on a silicon substrate, comprising:

a diode-pumped, solid-state laser assembly;

a controllable switch for controlling the on/off state and power level of the laser assembly; and

a computer programmed to control the laser assembly to cause the laser assembly to produce a laser beam output having an output pulse width less than about 8 nanoseconds at an operating repetition rate of 5 kilohertz or higher, and a wavelength shorter than 1.2 microns, the computer being programmed to cause the laser beam output to be directed at the target link structure on the silicon substrate to vaporize and remove the target link structure;

whereby heating of the silicon substrate and hence damage to the silicon substrate is limited due to the output pulse width being less than about 8 nanoseconds. –

REMARKS

Attached is a marked-up version of the changes being made by the current amendment.

Applicant submits that all claims are in condition for allowance, which action is requested.

Applicant asks that all claims be examined. Please apply any charges or credits to Deposit Account No. 06-1050.

Respectfully submitted,

Date: January 7, 2001

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<u>Version with markings to show changes made</u>

<u>In the specification:</u>

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where [η] **<u>E</u>** is the efficiency of conversion of pump light to laser output, P is the pump power (i.e., the effective power delivered by the laser diode), I_{sat} is a material parameter dependent on

the laser material and its doping, A_{pump} is the cross-sectional area covered by the pump beam in the laser rod, and A_{mode} is the cross-sectional area of the laser mode within the laser rod.

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Fig. 9 shows the [repetition rate] **pulse width** for the three different materials as a function of repetition rate. Not only does the YVO_4 (vanadate) have the shortest pulse width, but it maintains this pulse width over a very wide range.